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# V4332 Sgr in 'Quiescence'*

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**Abstract.** In 1994 V4332 Sgr underwent a mysterious eruption. Somehow its fast evolution towards a red giant star was, lacking alternative classifications, connected to the red variable M31 RV, which had its eruption in 1988. The red eruptive variable V838 Mon draw in February 2002 the attention back to its 'older twin' V4332 Sgr. The new precise photometry of the progenitor given here shows that the object started to rise years before the 1994 event. Post outburst photometry and spectroscopy from 2002 and 2003 show that the object stopped it's decline and seem to reheat now. The progenitor data and the new high quality spectra provide a supplement and completion to the data around the outburst given by Martini et al. (1999). It thus allows theorists to give new boundaries for modelling of this unusual object.

**Key words:** stars: individual: V4332 Sgr





## 1. Introduction

V4332 Sgr (Nova Sgr 1994 1) was discovered on February 24, 1994 by Hayashi et al. 1994. Already first spectra (Wagner 1994) indicated that this object was not a classical nova early in outburst. It lacked the spectral features characteristic for this class of objects. It then changed its spectral type from approximately M0 to M5 in 5 days only (Tomaney et al. 1994). Based on this kind of evolution they concluded that V4332 Sgr underwent a similar eruption like the luminous red variable in the bulge of M31 (M31 RV) discovered by Rich et al. 1989. A detailed review of the photometric and spectroscopic evolution of V4332 Sgr during the decline is given by Martini et al. 1999. To my knowledge, the last spectra before those presented here were obtained June 5-6, 1994 when the star had dropped to $V = 18\overset{\mathrm{m}}{.}7$. The same seems to apply to the photometry - except those from survey archives discussed later in this paper and a narrow band H$\alpha$ image obtained with HST in 1997.

I present here own spectroscopic observations and photometry obtained in August 2002 and in July 2003. Careful searches through the archives provided some additional data from HST (H$\alpha$ image taken November 3$^{\mathrm{rd}}$, 1997) and from the Asiago Observatory ($VR_{\mathrm{C}}I_{\mathrm{C}}$ frames taken May 16$^{\mathrm{th}}$, 2002). Finally I carefully collected and calibrated the progenitor data to have a better data base than that given in the first estimates by Wagner et al. (1994). As only the 1985 to 1992 sky survey plates are available in this region as digitized sky survey (DSS), I digitized with a CCD camera and a microscope POSS-I plate copies (observed 1950.53).

These data are discussed in connection with other data: low S/N optical spectra obtained in April 2003 (Tylenda et al. 2004) and in September 2003 (Banerjee & Ashok 2004) and near infrared data from DENIS, 2MASS and Banerjee et al. (2003, 2004a,b). Although there is an observational gap after the 1994 outburst it may provide clues to construct an unambiguous picture of this object. The spectra contain numerous strong unidentified emission features. These should be subject of a NLTE moving model atmosphere - including molecules.

## 2. Photometry

### 2.1. The interstellar extinction

Using the spectroscopic classification of Martini et al. 1999 and the photometry of Gilmore et al. (1994) and Wagner et al. (1994) for March 4 and 9 1994, I obtain an $\mathrm{E_{V-I}} \approx 0\overset{\mathrm{m}}{.}59$ ($\Rightarrow \mathrm{E_{B-V}} \approx 0\overset{\mathrm{m}}{.}42$), $\mathrm{E_{V-R}} \approx 0\overset{\mathrm{m}}{.}41$ ($\Rightarrow \mathrm{E_{B-V}} \approx 0\overset{\mathrm{m}}{.}35$), and $\mathrm{E_{B-V}} \approx 0\overset{\mathrm{m}}{.}29$. Although the star had changed from K4 to M3 the extinction values are consistent within the range of same bands for the two dates within $0\overset{\mathrm{m}}{.}01$. As the red bands are less affected by stellar lines and thus possible abundance effects, I give them a higher weight and thus get $\mathrm{E_{B-V}} \approx$

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* Based on observations collected at the European Southern Observatory, La Silla and on observations collected at Asiago observatory

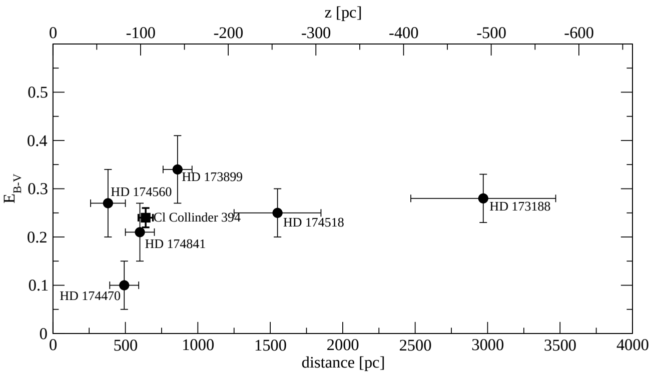


**Fig. 1.** The extinction-distance diagram for stars with well known spectral class and luminosity within 45′around V4332 Sgr. Additionally the well studied open cluster Collinder 394 is given. The extinction is constant for distances of $>$ 500 pc ($\equiv$ z $\approx$ 100 pc; upper axis).

$0\overset{\rm m}{.}37 \pm 0.07$ for V4332 Sgr. This is slightly higher but within the errors consistent with the value of $0\overset{\rm m}{.}32$ given by Martini et al. 1999.

From the SIMBAD data base all stars within a projected distance of 45′ from V4332 Sgr having well defined photometry and spectral types and a stellar open cluster were picked to derive an extinction-distance diagram. Recently Fröbich et al. (2005) used 2MASS star counts to derive the differential extinction for the whole galactic plane. It shows no variation within a square degree around the target. This justifies the use of such a large field. The results (Figure 1) show nearly no additional extinction left after a distance of 500 pc. The result also corresponds well to the total extinction of the Galaxy given for this field by Schlegel et al. (1998). Thus the extinction cannot be used to derive a distance like it is often used for such kind of unique objects (e.g. for V4334 Sgr by Kimeswenger (2002) or for V838 Mon by Munari et al. (2005))

### 2.2. Photometry of the progenitor

Sky survey plates scans from the pre-outburst period are available from the various online archives (see Figure 2). As the POSS-I plates are not available as scans south of $\delta = -17°$ I digitized with a CCD camera and a microscope POSS-I plate copies available at my institute. Further searches in plates archives of telescopes like Tautenburg, Kiso, Asiago etc. were carried out. But I failed to get additional pre-outburst plates being deep enough to show the target. I calibrated the scans using differential photometry and my CCD sequence in the field. For the conversion of the CCD magnitudes to the plate scale and the error estimates the recently published method my Bacher et al. (2005) was used. As shown there the error estimates are conservative. The Quick-V (1987.59) survey is not deep enough to give a reliable photometry of the target.

The star brightened in the red band ($E$ and $F$ bands are nearly identical to $R$ and thus comparable; Hörtnagl et al. 1992) by a factor of 10. This remarkable change cannot originate from a eclipsing binary system of normal main sequence

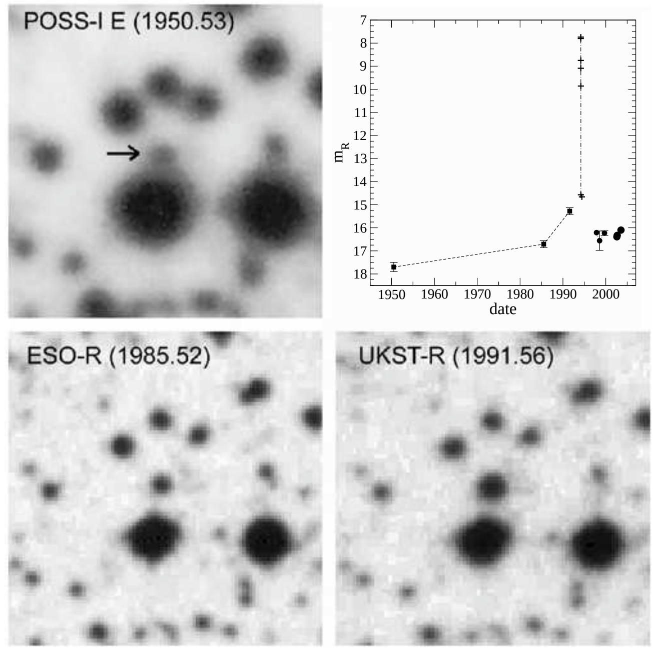


**Fig. 2.** The pre–outburst sky survey plates in the red band. The strong brightening is obvious here already. The red band photometry (insert) shows the total evolution of the target including the outburst data from Martini et al. (1999) and the post-outburst photometry derived here.

**Table 1.** Photometry of the pre-outburst phase.

| plate | date | band | mag |
|---|---|---|---|
| POSS-I blue | 1950.53 | $O$ | $19\overset{\rm m}{.}23 \pm 0\overset{\rm m}{.}12$ |
| POSS-I red | 1950.53 | $E$ | $17\overset{\rm m}{.}72 \pm 0\overset{\rm m}{.}10$ |
| UKST-B | 1976.57 | $B_J$ | $18\overset{\rm m}{.}01 \pm 0\overset{\rm m}{.}07$ |
| ESO-R | 1985.52 | $R_{59}$ | $16\overset{\rm m}{.}72 \pm 0\overset{\rm m}{.}05$ |
| UKST-R | 1991.59 | $R_{61}$ | $15\overset{\rm m}{.}28 \pm 0\overset{\rm m}{.}05$ |

stars as it is suggested in the model of Tylenda et al. (2004). The colors of this variable star from multi–epoch data (e.g. in the SuperCOSMOS catalogue) should not be used to estimate a spectral type and thus e.g. a distance. The only single epoch - multi color data point is available with POSS-I surveys (the plates were taken within the same night). With the interstellar reddening derived above, and the POSS-I photometry (using the color equations of Dorschner et al. 1966) I derive a spectral type of G2 ($\pm$ 0.4 subclasses). This results in a distance of 2.9, 5.8 and 10 kpc ($\approx$ 30% uncertainty) for luminosity class V, IV and III respectively. Thus the distance of 300 pc derived by Martini et al. (1999) is very unlikely - it should have been an extremely subluminous object. Such distances also fit well to the extinction-distance diagram given above. Tylenda et al. (2004) using $B_J$ from 1976 and $R$ from 1985 (both from the SuperCOSMOS catalogue) get, due to the steady rise in all bands, a later spectral type (G6 to K0) and thus a more nearby system.

Using the color equation of Blair & Gilmore (1982) for the $B_J$ band I derive a rise in $B$ band from 1950 to 1976 by $0\overset{\rm m}{.}9$ to $1\overset{\rm m}{.}0$ (uncertain by about $0\overset{\rm m}{.}2$ due to the color equation). As this is about the same amount like the total red increase from 1950 to 1985, one have to assume that the object

**Table 2.** Photometric results from CCD direct imaging:

| date | UT | telescope | band | mag |
|---|---|---|---|---|
| 11. Sep. 1999 | 00:29 | DeNIS | $I_{\mathrm{C}}$ | $14\overset{\mathrm{m}}{.}37$ |
| 16. May. 2002 | 02:35 | Asiago | $V$ | $17\overset{\mathrm{m}}{.}76$ |
| | | | $R_{\mathrm{C}}$ | $16\overset{\mathrm{m}}{.}37$ |
| | | | $I_{\mathrm{C}}$ | $14\overset{\mathrm{m}}{.}75$ |
| 6. Aug. 2002 | 00:30 | ESO NTT | $V$ | $17\overset{\mathrm{m}}{.}74$ |
| | | | $R_{\mathrm{C}}$ | $16\overset{\mathrm{m}}{.}39$ |
| | | | $I_{\mathrm{C}}$ | $14\overset{\mathrm{m}}{.}84$ |
| 31. Aug. 2002 | 23:50 | LCO-100 | $V$ | $17\overset{\mathrm{m}}{.}77$ |
| | | | $R_{\mathrm{C}}$ | $16\overset{\mathrm{m}}{.}33$ |
| | | | $I_{\mathrm{C}}$ | $14\overset{\mathrm{m}}{.}92$ |
| 20. Jul. 2003 | 01:20 | ESO NTT | $V$ | $17\overset{\mathrm{m}}{.}59$ |
| | | | $R_{\mathrm{C}}$ | $16\overset{\mathrm{m}}{.}10$ |
| | | | $I_{\mathrm{C}}$ | $14\overset{\mathrm{m}}{.}95$ |

got redder ($\Delta_{B-V} \approx 0\overset{\mathrm{m}}{.}2 - 0\overset{\mathrm{m}}{.}4$). Thus the bolometric luminosity rises a little bit less than the factor of 10 found in the $R$ magnitude.

The only epoch were 2 bands were taken more or less simultaneously was 1950. Thus color estimates and thus estimates of the spectral type of the progenitor are extremely difficult. Color equations derived for normal stars were applied. Thus this determination is only reliable under the assumption that the object was not an emission line star at that time.

### 2.3. The post-outburst photometry

I have taken direct images with $VR_{\mathrm{C}}I_{\mathrm{C}}$ bands shortly after the spectra discussed later. Additionally Martini 2003 provided me with images taken a few weeks after my 2002 ESO run at the Las Campanas 2.5m telescope. Both - absolute and differential photometry was carried out with these images. The original DeNIS survey image ($I_{\mathrm{C}}$) was taken from the consortium data base and calibrated differentially with the NTT CCD frames. This gives a better result than the survey calibration. In the Asiago Observatory archive I found a set of direct images taken May 2002. The accuracy of the photometry given in Table 2 is better than $0\overset{\mathrm{m}}{.}03$ throughout all bands.

In the HST archive a H$\alpha$ image taken November 3$^{\mathrm{rd}}$, 1997 was found. This filter is well centered on the effective wavelength of the $R$ band. As the CaI (657.3nm) line contributes to the flux, I folded the spectrum with the filter curve. This was used to correct for the contamination by this emission line (Figure 3). To test the procedure the 2002 and 2003 $R$ band photometry was compared in the same way by using "artificial" images folding the spectra with the published filter curve. There the deviation was less than $0\overset{\mathrm{m}}{.}05$. The error using the UKST-H$_\alpha$ photographic survey (taken 2002.5) in the same way is $0\overset{\mathrm{m}}{.}1$. Thus the error estimate of $0\overset{\mathrm{m}}{.}15$ given in Figure 4 is certainly conservative.

Banerjee & Ashok 2004 published photometry from 29$^{\mathrm{th}}$ Sep. 2003. I included the $V$ band in the analysis. For the $R$ and $I$ band it is not clear whether Cousins, Bessel or Johnson filters were used. The GSC 2.2.1 gives us $R = 16\overset{\mathrm{m}}{.}56$ for 1998.54. Comparing about 10 nearby stars from that GSC calibration with my CCD set leads to a shift of $+0\overset{\mathrm{m}}{.}02$ with a

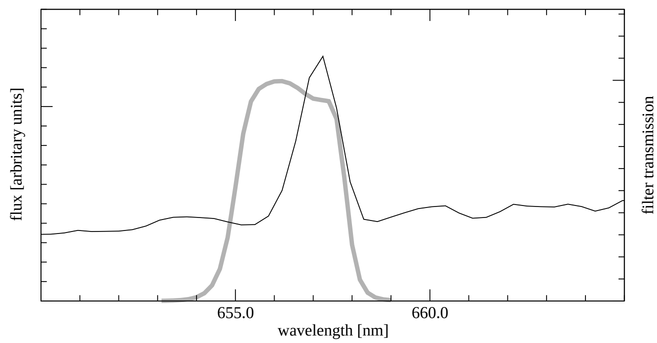


**Fig. 3.** The CaI (657.3nm) contamination in the HST H$\alpha$ filter (grey line).

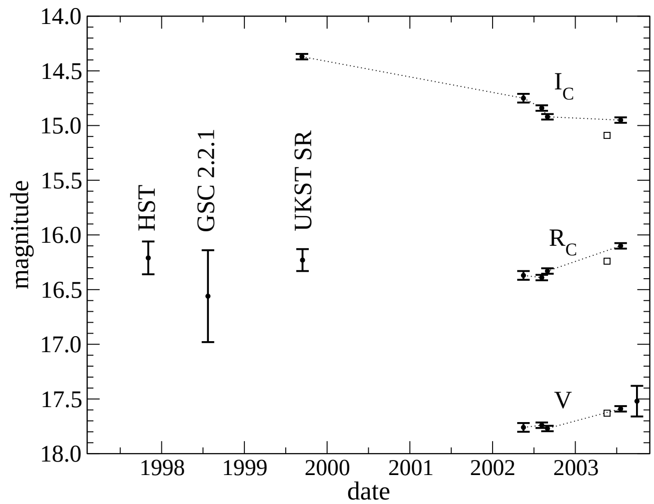


**Fig. 4.** Recent photometric evolution of V4332 Sgr. While the $I_{\mathrm{C}}$ flux faded 1999 to 2002 it was stable thereafter. The flux in the $V$ and $R$ bands started to rise again.

rms of $0\overset{\mathrm{m}}{.}07$. Thus the error of $0\overset{\mathrm{m}}{.}42$ given in the catalogue is, for my point of view, too high. Finally a short 4 minute exposure red plate, taken as continuum subtraction image for the UKST-H$_\alpha$ survey, from 1999.7 exists. It was calibrated in the same way as the progenitor photometry.

As shown in Figure 4 the target stopped it's decline and started to get even a little bit hotter now. However this interpretation of the broad band photometry has to be used carefully. The spectrum is dominated by emission lines, producing a significant fraction of the flux. Banerjee et al. 2003 find a decline in $J$ between the 1998 2MASS measurements and their 2003 data. Taking the $(R-J)$, which changed from $\approx 4\overset{\mathrm{m}}{.}0$ in 1998 to $2\overset{\mathrm{m}}{.}89$ in 2003, gives another signature of heating – on the other hand the $K$ band shows an increasing IR excess. Thus the bolometric luminosity clearly increased from 1998 to 2003.

Assuming the contamination by the dust shell built during the late 90s to be negligible in the $J$ band (Banerjee et al. 2003) I derived, using intrinsic colors of real stars (Cox 2000), an effective temperature of 3.900 K and a circumstellar extinction, additional to the interstellar extinction derived during the outburst phase, of $\mathrm{E}_{B-V}=0\overset{\mathrm{m}}{.}44\pm0\overset{\mathrm{m}}{.}05$. This temperature is significantly higher than the 3.250 K derived by the simple blackbody fit in Banerjee et al. 2003. As shown in

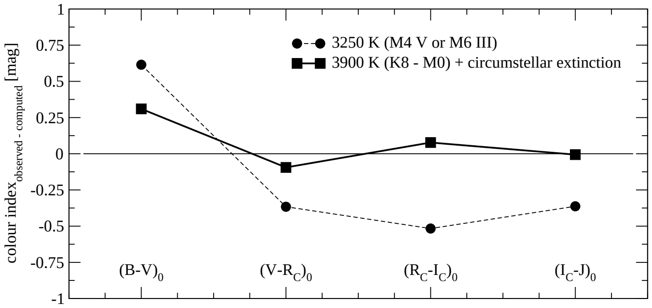


**Fig. 5.** The temperature of the "photosphere" during 2003. The K8-M0 star adding an additional circumstellar extinction gives a much better fit than the M4-M6 star derived by Banerjee et al. (2003).

Figure 5 the hotter star with the additional extinction is consistent over a large wavelength range. This results in a temperature of 865±20 K for the temperature of the dust shell causing the near infrared excess. This is slightly lower than the previously derived temperature of 900 K (Banerjee et al. 2003).

## 3. Astrometry

To possibly estimate a proper motion (if the distance of 300 pc of Martini et al. 1999 applies), the images and the four sky survey plates were calibrated astrometrically. For the calibration in the modern ICRS 2000 frame, I used the *USNO CCD Astrometric Catalogue* (UCAC) (Zacharias et al. 2000). Andersen & Kimeswenger 2001 show in detail the accuracy of this method and strict bounding to the TYCHO-2 reference frame. This leads to the very accurate coordinates on the CCD frames (epoch 2002.66 / equinox J2000.0)

$$\alpha_{\rm ICRS} = 18^{\rm h}50^{\rm m}36\overset{\rm s}{.}713 \quad \pm\, 0\overset{\rm s}{.}005$$
$$\delta_{\rm ICRS} = \text{-}21^\circ 23' 28\overset{''}{.}94 \quad \pm\, 0\overset{''}{.}03$$

The numerical solution for the proper motion for the sky survey plates, with the epochs 1976.567 (UKST-J), 1985.519 (ESO-R), 1986.686 (UKST-IR) and 1991.581 (UKST-R) gives no significant proper motion. The HST archive image (H$\alpha$ narrow band) taken 1997.841 covers only a very small region around the target. It thus was calibrated relative to the global solution obtained above. Using 8 surrounding stars relative to the 2002.66 and the 2003.61 NTT images gives an upper limit of 4 mas/yr. As we are looking towards the galactic center, differential shear due to the rotation should be significant. This upper limit, not necessarily but most likely, excludes also a short distance scale of 300 pc of Martini et al. 1999.

## 4. Spectroscopy

### 4.1. Data

The spectra were taken at the ESO New Technology Telescope August 6, 2002 (+EMMI red arm) and July 20–23, 2003 (+EMMI red & blue arm). At the red arm grism #2 and slit width of $1\overset{''}{.}0$ was used. This gives a resolution (binning the CCD 2×2) of ≈0.3nm/pixel. The FWHM of night sky lines is 0.91nm, giving us the real resolution. The usable range of the spectrum spans from 450nm to 960nm. In July 2003 spectra with the EMMI blue arm and grating #5 were taken, resulting in a similar resolution and in a range of 350nm to 550nm. As the signal was very weak below 400nm this region was not used for the final spectrum. The data were reduced, using standard techniques in MIDAS and calibrated using the standard stars G93-48, LT 6248 and EG 274. The full observational log is given in Table 3. The 2002 spectrum (medium S/N) and 2003 spectra (high S/N) were overlayed. Except the changes in the KI and in the NaI lines (see below), no significant variations (within the errors) were found. Thus I was able to combine them. The spectrum is shown in Figure 6. The spectrum may be obtained from the author electronically on request. All the tiny structures down to $5 \times 10^{-19}$ W m$^{-2}$ nm$^{-1}$ (half a tick in Figure 6) are visible in all spectra and thus have to be real. The S/N was derived from the MIDAS data reduction for the continuum for a single spectrum. Additionally deviations in the region of the telluric bands was taken from the standard stars and multiplied by a factor of 3 to achieve a conservative error estimate. The S/N in the strong lines thus is even much better. Furthermore the combination of all spectra gives another improvement of about a factor of 2. Another check for the reliability is derived by dividing the spectrum obtained 2003 July 20 and that obtained July 23. Even at the position of the telluric bands the deviations are below 3%.

**Table 3.** Observational log of the spectroscopy:

| date | UT start | exp. time | mode | airmass seeing |
|---|---|---|---|---|
| 6. Aug. 2002 | 00:19 | 300 | EMMI Red Arm | 1.17 |
| | | | Grism #2 | $1\overset{''}{.}3$ |
| | 00:25 | 300 | EMMI Red Arm | 1.16 |
| | | | Grism #2 | $1\overset{''}{.}3$ |
| 20. July 2003 | 00:37 | 1200 | EMMI Red Arm | 1.36 |
| | | | Grism #2 | $1\overset{''}{.}4$ |
| | 01:20 | 250 | EMMI Blue Arm | 1.19 |
| | | | Grating #5 | $1\overset{''}{.}5$ |
| | 01:30 | 1800 | EMMI Blue Arm | 1.17 |
| | | | Grating #5 | $1\overset{''}{.}3$ |
| 21. July 2003 | 23:35 | 1800 | EMMI Blue Arm | 1.71 |
| | | | Grating #5 | $0\overset{''}{.}9$ |
| 22. July 2003 | 00:15 | 1200 | EMMI Red Arm | 1.42 |
| | | | Grism #2 | $0\overset{''}{.}8$ |
| 23. July 2003 | 00:05 | 1800 | EMMI Blue Arm | 1.46 |
| | | | Grating #5 | $1\overset{''}{.}0$ |
| | 00:43 | 1200 | EMMI Red Arm | 1.28 |
| | | | Grism #2 | $1\overset{''}{.}1$ |

### 4.2. Line identification

As already pointed out by Banerjee & Ashok 2004 the spectrum is dominated by the NaI (589.0 + 589.6 nm) and the KI (766.5 and 769.9 nm) lines. The S/N of my composite spec-

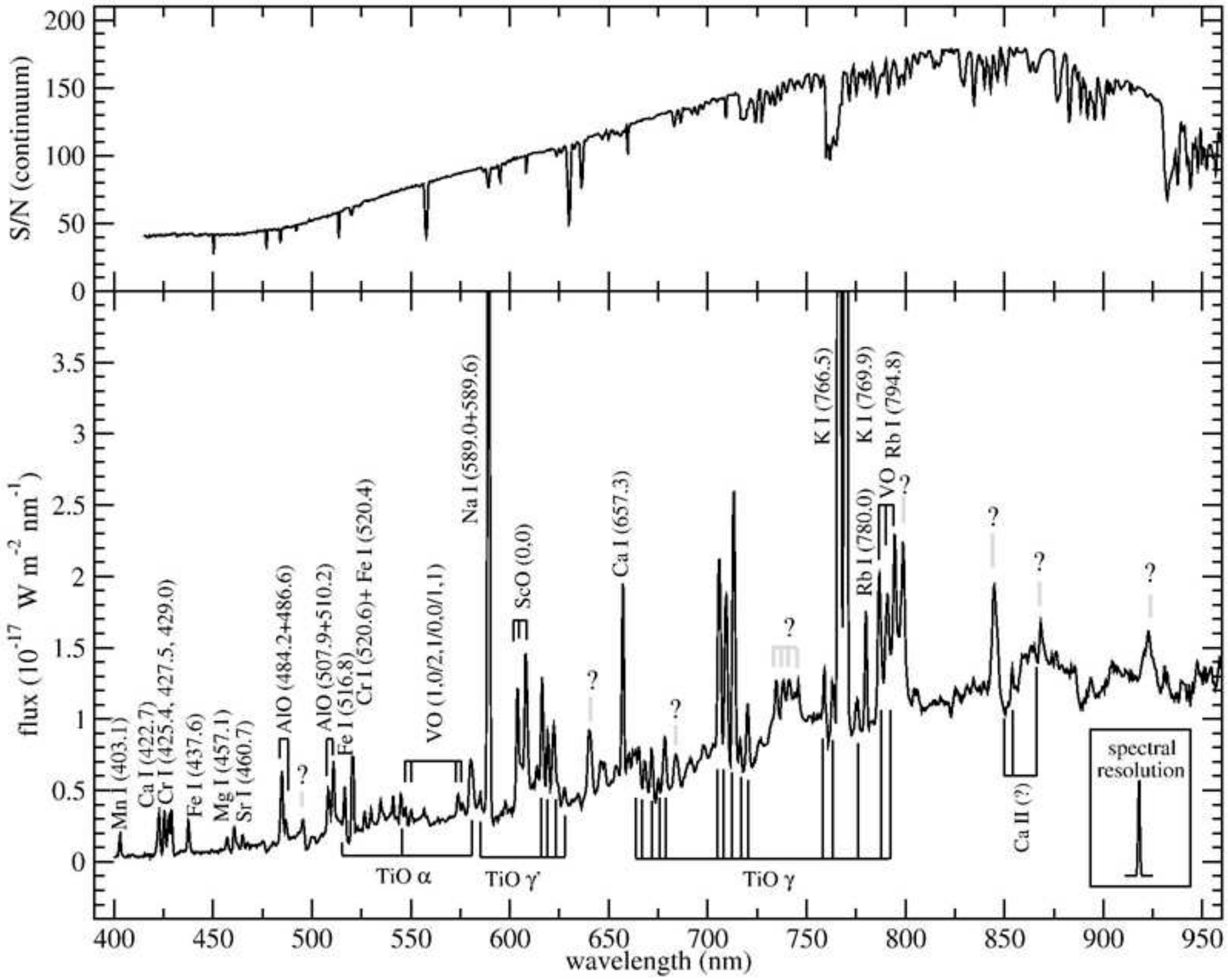


**Fig. 6.** The spectrum of V4332 Sgr taken in July 2003. The NaI (589.0 + 589.6 nm) and the KI (766.5 and 769.9nm) are truncated in order to see all the weaker features. The slope of the continuum is consistent with the photometric results. The main features are marked. Strong, but unidentified features are marked with grey tics. The insert shows the gaussian with the FWHM of the night sky lines. The upper panel shows the calculated S/N ratio from the data reduction (continuum). In the region of the telluric bands the deviation between the standard stars was taken and multiplied with a factor of 3 to achieve a conservative estimate for the errors.

trum is significantly better than that given there. Thus it is easier to distinguish between bundles of blended lines and continuum. This is essential to define the real fluxes (resp. equivalent widths) of the lines. The identifications of the strong features found by Banerjee & Ashok 2004 mostly can be confirmed.

Their identification of VO(0,0) 608.6 nm is more likely connected, together with the strong feature around 603.5 nm, to ScO(0,0) (603.6 + 608.0 nm) - especially as overtones fill the gap between them in the same way as in VY CMa (Herbig 1974, Wallerstein & González 2001). Their identification of TiO $\gamma'$ (0,1) at 656.9 nm should be more likely replaced by CaI 657.3 nm ($\chi = 1.9$ eV) due to missing other lines of this TiO band. This CaI line also has an excitation very similar to the strong KI and NaI features. Also the other line from the ground state of CaI at 422.7 nm (2.9eV) is very prominent.

As strong low excitation metal lines (NaI and KI) changed while molecule emission did not vary (see below), the classification of the 780.0 and 793.9nm features as RbI by Banerjee & Ashok might be under discussion. It should follow a change in line optical depth of the emitting gas. These features might originate from the TiO$\gamma$(2,3) and (3,4) series and the VO features as found also in CY CMa (Wallerstein 1971, Herbig 1974, Wallerstein & González 2001) and in case of the unusual M giant U Equ (Barnbaum et al. 1996) as well. As the line ratio of these two emissions cannot be reached by RbI for gas temperatures below 15.000K, at least some contamination has to exist. Several other strong features cannot be identified at all. Although it is nearly always possible to find a low excitation line for a given wavelength, as other lines of the same multiplet are missing these identifications cannot be taken into account. The FeI identifications have to be discussed. The ratio of the line at 516.8nm to that

at 520.4 nm (contaminated by CrI 520.6 nm) and the missing 522.5 and 626.9 nm lines do not fit well to the interpretation below. No lines with upper levels above $\approx$ 3.1 eV are found. This results in a electron temperature for the emitting region of $\leq$ 2.200 K. Table 4 gives all well defined lines and features. To derive equivalent widths a Kurucz (1991) model having 3.900 K was used as continuum (see next section). This certainly is the largest source of uncertainty in the line strengths.

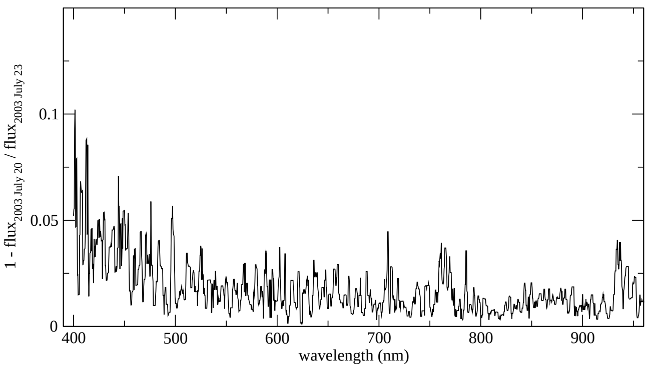


**Fig. 7.** The quotient of the 2003 July 20 spectrum over the 2003 July 23 spectrum shows deviations of a few percent even in the region of the telluric bands.

### 4.3. The continuum

To derive, independently from the broad band photometry above, the underlying continuum of the central source, a spectroscopic comparison was started. To normalize the continuum only the lowest points at 450, 530, 660, 705, 825 and 925 nm were taken for a spline fit. This restriction guaranties no contamination by molecular bands even for very late spectral types. The resulting spectrum was overlayed with Kurucz (1991) model atmospheres and $\chi^2$ was derived. Most of the prominent absorption bands fit very well with the 3.900 K derived also in the photometry. Some small bands may give a little bit lower temperature down to 3.700 K - but none goes as far down as found by Banerjee et al. 2003. Thus the 3.900 K photosphere of the central source was adopted for the further analysis.

### 4.4. Interpretation of the spectrum

The molecular lines stay remarkably stable - both, between my spectra in 2002 and 2003 as well as compared to the spectrum of Banerjee & Ashok 2004. Only the 708.7 nm TiO$\gamma$(0-0) feature looks different in the spectrum of Tylenda et al. (2004). I obtain a temperature of 600 K for the ScO lines using the calibration by Herbig (1974) and about 700 K for the TiO$\gamma$ lines using the transition strengths in the online Kurucz tables. Banerjee et al. 2003 derived somewhat higher values of 3.000 K for the near infrared AlO vibrational excitation. On the other hand they get only 300K for the rotational terms. This emission either originates from different spatial domains or from a region without thermodynamic equilibrium. Generally the molecular lines fit well to the dust temperature of 865 K derived by the NIR excess.

The atomic lines unveil a very complex situation. The 766.5 nm KI line is affected by the telluric band. Thus it is critical to derive the underlying continuum and thus the correct ratio of the two lines. The total strength increased by 13% between summer 2002 and summer 2003. The accuracy of about ±5% is due to the strength of the lines in my spectra despite the problems with the telluric bands. The ratio of the 766.5 nm to the 769.9 nm line do not satisfy the expected one for (in the line) optically thin media, (except if we go down to 147 K - but then the emissivity itself is negligible and the line should not be visible). Banerjee & Ashok 2004 use an access given by Williams 1994 to derive an optical depth for self absorption in the line, assuming a ratio of 2:1 (which corresponds to an electron temperature of $\geq 2.500$ K). This access also assumes an isothermal and homogenous plane-parallel slab. Remarkable is that the optical depth decreased from $\tau = 4.9$ in 2002 to $\tau = 3.4$ in 2003. Banerjee & Ashok 2004 give for September 2003 a value of 4.5. On the other hand the red line (unaffected) increased further by another 10% from July to end of September 2003. Although this may be reached also by an increase of the electron temperature, it is likely a decrease of the optical depth. Thus it is unclear whether this turnaround is real or just an effect of an improper continuum subtraction and correction for the telluric band for the blue line in the low-S/N spectra by Banerjee & Ashok 2004. The absolute values of $\tau$ should not be used to derive column densities, as the less optically thick line comes from a smaller but hotter region deeper inside the circumstellar environment. The increase of the line strength in the NaI lines is even stronger (+27%). Also here the line increased further by another 16% until September. As this line is, due to the higher abundance of the element, much more optically thick than KI, it shows the thinning of the outer layers more drastically. Finally the CaI 657.3 nm seems not to change. As the blue spectral range was not covered in 2002 the other low excitation species cannot be compared.

The ratio of the CaI 657.3 nm to CaI 422.7 nm gives, for an optically thin line, an electron temperature of 1.000±30 K. This line ratio is very sensitive to temperature. Both lines are getting optically thick very quickly due to the high abundance of the element. Thus it is likely that they originate from a thin, and thus isothermal, layer at the outermost part.

Assuming solar abundances for NaI and 766.5 nm KI I derive an excitation temperature of 1.050 K. The FeI lines has strong variations in their transition probabilities. Therefore the optically depths vary from line to line. We "see" different regions with each line. No real temperatures can be derived. All solutions tend to go towards temperatures above 1.700K. The optically thin solutions for CrI 425.4, 427.5, 429.0 + 520.6 nm (in fact a blend of 520.45 + 520.6 + 520.8 nm) gives 1.350 K. But again the line with the highest transition probability (429.0 nm) is overestimated in the calculation. This again leads to line self absorption and thus underestimates the real temperature. This is especially supported by the observed line strength of the 520.6 nm feature. This only identified transition in my spectrum not going to the ground state of

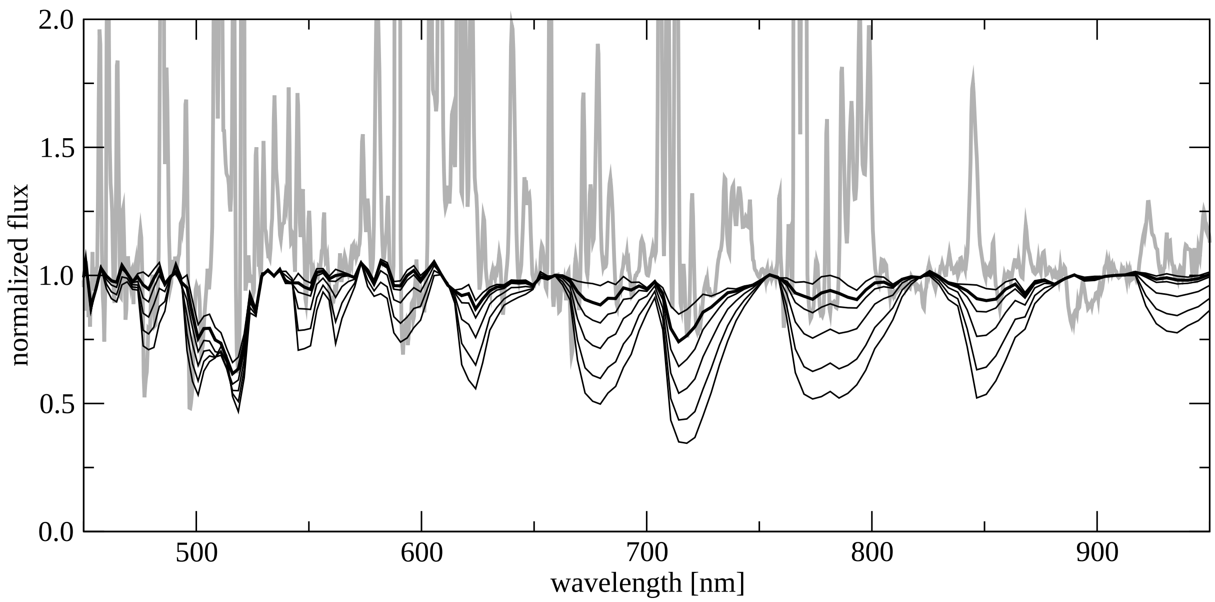


**Fig. 8.** The normalized spectrum (grey line) and Kurucz (1991) model atmospheres for 3.500 to 4.000 K (step 100K).

**Table 4.** Lines of the spectrum: $\lambda_{obs} =$ observed wavelength using gaussian fit; $EW := \sum (F_c - F)/F_c \ d\lambda$

the atom. On the other hand it has an unknown FeI contamination. The RbI doublet seems to be contaminated (see discussion above). For all other elements (MnI, MgI, SrI) only single lines are available. Thus temperatures can be derived only by assuming an abundance, relative to other elements. Using solar abundance temperatures like those for FeI are derived.

## 5. Results

V4332 Sgr underwent a mysterious eruption. The nature of the event remains unclear. The photometric behavior before the outburst with an amplitude of $\Delta R \geq 2\overset{\mathrm{m}}{.}4$ is an argument against the scenario of a main sequence stellar merger (Soker & Tylenda 2003, Tylenda et al. 2004). Such a high amplitude cannot be produced by an eclipsing MS binary system. Also the merger should give a sudden onset of the envelope expansion. Thus the brightening cannot be a forerunner of the event. This applies even more for the planet destruction suggested by Retter & Marom 2003. This amplitude resembles more likely the variations of CVs from "on" to "off" phases. The stable red band photometry (the bolometric correction for the $R$ band is for such stars rather small) and the (marginal) luminosity increase during the recent years also is not expected for a post-merger scenario. Tylenda et al. (2004) predict a steady decreasing luminosity ($\approx 1\overset{\mathrm{m}}{.}0$ since the HST data). This clearly is not the case. The star has not declined completely to its pre-outburst luminosity yet, and shows a much cooler atmosphere than that of the pre-outburst.

The photometry and the investigation of the underlying continuum reveals a K8-M0 stellar atmosphere. This leads to a revision to earlier studies, that the circumstellar dust, built 1998-2000, do not give any continuum extinction. For such a photosphere the luminosity is fitted to the photometric data by

$$\log L = 2 \times \log D - 5.7063 \qquad (1)$$

where $D$ is the distance in units of $pc$. At the distances derived from the progenitor this luminosity is too high for am M0V star.

Dust (assuming no shock heating) at a temperature of 865 K is then at a distance of about 10 stellar radii ($R_*$). As there are found no evidence for fast flows (e.g. no HeI 1.08$\mu$m and no P-Cygni line profiles) this assumption seems do be reasonable. The dust gets rapidly cooler at larger distances. Thus already at a distance of $13 - 15R_*$, even assuming constant density, the contribution to the NIR excess gets negligible. Thus a dust mass estimate from the NIR flux leads to an underestimate of the real values. Estimates using the NILFISC code (Koller & Kimeswenger 2001) for the circumstellar extinction leads to a much larger extent of the absorbing dust shield. Without a detailed geometrical model (disk vs. shell and density profile) this question cannot be settled. Some hints for a complex non spherical geometry might be given by the fact that the atomic lines are blueshifted with respect to the molecular lines. But higher spectroscopic resolution is needed to confirm this. An observation like it was tried recently for V838 Mon by Lane et al. (2005) up to now fails due to the faintness of the target even in NIR bands.

For a complete analysis of the emission spectrum a full radiative transfer (RT) have to be calculated. But as the current observations do not allow to verify whether the emitting layers have a hydrostatic stratification or are part of an self contracting shell. As the line optical depth is clearly above unity in the lines and, as the underlying stellar photosphere

gives optical depths below unity in the continuum, a full non-LTE radiative transfer have to be calculated to derive a full spectrum and reliable abundances. All this requires some assumptions on the geometry.

For the investigation of the geometry, very high spectral resolution giving line profiles and the relative blue/redshifts of the lines are required.

The cold material is either a shell of very clumpy clouds, or - more likely - an equatorial disk. The latter makes, so massive shortly after the event, a scenario with a single star (e.g. an He shell flash) very unlikely. A Nova event with a massive shell, as suggested by Martini et al. 1999 to model the moving ”quasi photosphere”, might be a possible explanation. Shara et al. 1993 and Prialnik & Kovetz 1995 predict such massive shells on WDs with masses as low as 0.6 $M_\odot$ - thus novae during their first few recurrent events. This is not in contradiction with the missing of $^{26}$Al (Banerjee et al. 2004b). Starrfield et al. 1997 points out that the ratio $^{26}$Al/$^{27}$Al in Novae with low mass WDs might be as low as 0.01. Also the low expansion velocities measured for V4332 Sgr (Martini et al. 1999) are in agreement with the low mass WD models (Kato & Iben 1992). Even if the model of Iben & Tutukov 1992 does not work directly, the results of Shara et al. 1993 for a 0.4 $M_\odot$ He-WD look promising for the multiple outbursts like those seen in V838 Mon and should be discussed also with respect to this kind of objects. They show in their model a delay of the second outburst when waiting for the expansion of the envelope after convection recedes from the surface.

V838 Mon and V4332 Sgr are sometimes also discussed in relation to born-again PNe and late He-flash post-AGB scenarios. The ScO and AlO molecules in emission are a signature of a very O-rich ejecta. This is somehow in contradiction to the models, predicting a C-rich shell (Herwig et al. 1999).

Generally it is somewhat puzzling to me that the disk seemed to be formed years later after outburst when the photometric behavior have already ”stabilized”. The pre-outburst behavior, rising during several decades, differs completely from that of V838 Mon. That object was stable before the outburst (Goranskij et al. 2004). Boschi & Munari 2004 suggest in their conclusion that *”this kind of results support the need of radically new models for M31-RV and V838 Mon and V4332 Sgr.*”

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